Highway Research Correlation Service

HIGHWAY RESEARCH BOARD of the

National Academy of Sciences—National Research Council

2101 Constitution, Washington, D.C.

MARCH 1960 CIRCULAR 416

Highway Research Board Committee Activity

COMMITTEE ON MINERAL AGGREGATES

DEGRADATION OF AGGREGATES USED IN BASE COURSES AND BITUMINOUS SURFACINGS

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A degrading aggregate in a base course was first brought to the author's attention in 1955 when a road in northern Idaho developed considerable material passing the No. 200 sieve during the first winter's service. This road was unpaved at the time and the material became so dense and impermeable that potholes would not drain water, even though the underlying base was a crusher-run product that was very open graded.

The Washington Department of Highways had earlier experienced similar degradation on a section of highway on the Olympic Peninsula. They had begun to study test methods to help them predict the action of rock in service.

Oregon and Iowa reported similar experiences at the 34th Annual Meeting of the Highway Research Board in 1955.

Idaho has experienced failure of about 35 mi of highway from the use of a degrading aggregate. The first project, eleven miles in length, was constructed during 1954 and failure was evident, during the spring of 1955. Another project, about 20 miles in length and constructed during 1956, failed in 1957; another, constructed in 1958, showed evidence of failure in 1959.

In northern Idaho the problem exists where basalt rock from the Columbia Basin is used. Oregon reports similar problems with basalt, although the type of failure there is from different causes than in Idaho. Washington has experienced degradation with sand and gravel on the Olympic Peninsula, and apparently with some other materials throughout the state.

Normally, these materials will pass all of the usual tests for quality, such as the Los Angeles wear, sodium soundness, and similar type tests. The evidence indicated in Idaho is that the coarse aggregate apparently does not break down seriously, although there is slight degrading of the plus No. 4 material. As the aggregate size becomes smaller, it appears that the amount of degradation increases in proportion to the fineness of the material. The result is a great increase in the percentage passing the No. 200 sieve. This material often is quite plastic, resulting in a dense impermeable base course unsuited for the base of a pavement.

The HRB Committee on Aggregates directed the author to report on this problem. A questionnaire was submitted to each of the 50 states and Washington, D. C., during the early summer of 1959 to determine the extent of the problem. A copy of this questionnaire is included as Appendix A and the results of the questionnaire define degradation as:

> "A breaking down and/or disintegration of particles of sand, gravel, or stone, primarily due to the alteration and subsequent decomposition of their mineral components, accelerated by the action of mixers, mechanical equipment, traffic or the elements."

ANSWERS TO QUESTIONNAIRE

The questionnaire brought forth 46 replies, including replies from Puerto Rico and Hawaii. Thirty-six of them report that degradation has occurred, seven say it was serious, fifteen moderately serious, and seventeen insignificant. Four report that it was non-existent and three did not answer the question.

J. R. Schultz, Engineer of Materials for Wisconsin, states: "It is only recently that we have become convinced that the cause of yielding bases, leading to failure of a number of hot-mix mats through disintegration by alligator cracking, was an increase in the fraction passing the No. 200 sieve during service. Investigation of such failures and crushed stone bases produced from the softer limestone in our state always disclosed dust contents from 15 percent to as high as 20 percent plus. In the lower ranges there was the question of degradation during the construction manipulation, but in the higher ranges continuing degradation during service seems the only possible reason for the fines buildup."

Bert Myers, Materials Engineer of Iowa, furnished a tabulation of the results on nine projects, giving the gradation of the material before compaction, after compaction, and after two years or more of service. These all indicate degradation of the material in service.

Carl Minor, Materials Engineer of the State of Washington, furnished a progress report on their studies of this particular problem and a report by their state geologist on the types of materials throughout the state wherein they have had this trouble.

The similarity of the problems reported by these three states and with experience in Idaho, the troubles reported by Scott of Oregon, and the results of the questionnaire, lead to the belief that the problem is of greater magnitude than was originally considered.

Thirty replies reported that the Los Angeles rattler test, 21 the sulfate soundness test, and 13 the freeze-and-thaw test, did not differentiate degrading aggregates from good aggregates. Eleven report on tests that they considered helpful in separating degrading aggregates from good aggregates. Some reported that a combination of tests, such as the Los Angeles rattler and soundness tests, would help them to differentiate between degrading aggregates and good aggregates. Eight reported that their tests were satisfactory. However, some of the tests reported as satisfactory in one instance would not be satisfactory in another. Three states reported that they are able by visible means to identify and eliminate from use sources subject to degradation.

Tests or means reported as helpful in identifying degrading aggregates are as follows:

1. A modification of the Los Angeles rattler test, using 30 lb of graded material from 3/4-in. to dust, and 1,000 revolutions without a steel charge. The material, after coming from the Los Angeles rattler, is tested for plasticity index, sand equivalent, and increase in percentage passing all the sieves. A comparison is then made with the original material to decide the extent of degrading.

2. The ratio for the percentage wear at 100 and 500 revolutions in the Los Angeles rattler test.

3. The Los Angeles rattler test values taken together with absorption on the aggregate or sulfate soundness tests on the aggregate.

4. A knowledge of local materials together with the Los Angeles rattler test.

5. The kneading compactor has been used to degrade material kept saturated.

6. Tumbling (1000 revolutions) a sample of aggregate in a jar in the presence of a small amount of water and then measuring the cleanness of the material after tumbling.

7. The scratch test, using brass rods in accordance with ASTM procedures.

8. Sulfate soundness tests.

9. Petrographic analysis of thin sections.

10. Specific gravities of aggregates when taken together with porosity and permeability of the material.

11. Microscopic examination of the material.

12. The Texas wet ball mill test.

13. The Deval wear test.

14. The wet preparation of the sample.

15. Visual examination of the material.

Several report the use of two or more tests to endeavor to identify these materials. Copies of test methods used in Idaho are included in Appendix C.

In reviewing tests reported as helpful, it is often evident why the tests might be helpful for some materials (that is, the use of the Los Angeles rattler test on a sandstone, which might differentiate, degrading sandstones from the better sandstones, whereas the Los Angeles rattler test values for basalts or limestones would not be as readily interpreted).

When reviewing the aggregate classifications reported as degrading, some states reporting several as giving trouble, it is evident that the sedimentary stones are largely responsible. Fifteen reported limestone, or types of limestone, as giving difficulties; thirteen, sandstone; eleven, shale, slate or siltstone; seven, weathered granite; six, schist; six, a general classification of gravel; three, basalt; three, dolomite; two, gneiss; and one each, volcanic tuff, serpentine, slag, dunite, chert, coal, scoria, andesite, calcite, iron ore, and diabantite coating on diabase.

In reply to an HRB staff questionnaire asking (a) how soft a stone can be and yet give satisfactory service in portland cement concrete pavement where durable and wear-resistant fine aggregate is available, and (b) the criteria by which it is judged when stone is or is not satisfactory, many states reported results of Los Angeles rattler wear as much as 50 percent and South Carolina reported 66 percent wear with satisfactory results. Many states report sodium sulfate losses as high as 15 percent with satisfactory performance indicated.

These results indicate that base course service might possibly be more severe than that of concrete pavements.

TREATMENT OF DEGRADING AGGREGATES

Only a few attempts at treating degrading aggregates were reported. Washington and Wisconsin report using portland cement as a means of reducing the amount of degradation. Nevada reports using a heavy seal coat to prevent water from percolating into the pavement structure and causing difficulty. New Hampshire reported they had crushed and washed an aggregate twice in an effort to reduce degradation, but found it ineffective. California and others report limiting mixing time in concrete transit mixers.

Idaho has used a highly cracked asphaltic road oil, and SS-1 emulsion on two projects. The latest project to cause difficulty was treated as an experimental project using portland cement, lime, cracked road oil and SS-1 emulsion. This project was treated in September 1959, but is barricaded until the summer of 1960, when a bituminous surfacing will be applied before opening the road to traffic.

Others report limiting the weight of rollers and crushing to the coarse side of specifications as a means of assisting them in controlling degradation. No information is furnished to indicate the success of these treatments. It may be reported, however, that the bituminous treatments in Idaho appear to be entirely satisfactory after $1\frac{1}{2}$ and 4 years service, respectively.

CONCLUSION

There is a basic need for a test, or tests, that will identify degrading aggregates. The tests should indicate the change in gradation and the character of the end product. In many areas degrading aggregates must be used, and treatments should be developed.

In reviewing the questionnaire, specifications and literature, it appears that present tests in use are applicable only to coarse sands and stone. The fine sands and material passing the No. 200 sieve in base and surfacing material have been tested only for identification, and not for resistance to degradation or development of plastic fines. A need exists for the development of tests to predict the performance of the total product used and of means of predicting performance of treated material.

Appendix A

The Pacific Northwest States have experienced some difficulty with degrading aggregates. This experience indicates that more than one type of material (geologically) and both sand-gravel mixtures and crushed stone do break down or degrade. This questionnaire requests your assistance with this problem. Please submit your answers to:

L. F. Erickson, Materials Engineer
Idaho Department of Highways
Boise, Idaho

For purposes of this questionnaire, degradation of aggregates is defined as follows:

> "A breaking down and/or disintegration of particles of sand, gravel or stone, primarily due to the alteration and subsequent decomposition of their mineral components, accelerated by the action of mixers, mechanical equipment, traffic or the elements."

Please answer the following questions:

1. Have you experienced degradation of aggregate in your state?
2. Have these degrading aggregates passed normal acceptance tests; i.e., L. A. wear, soundness, freeze-thaw?
3. Do you consider the problem in your area to be serious, moderately serious, insignificant or non-existent?
4. What type material (geologically) is responsible for degradation most pronounced?
5. What have these degrading aggregates been used for? Concrete, asphaltic concrete, bituminous surfacing, base or subbase?
6. Have tests been developed to determine susceptibility to degradation? Please give references to tests used and/or attach copy.
7. Do above tests serve satisfactorily?
8. Have treatments been developed to prevent degradation in use?
9. Describe treatment. Please give references to methods employed.
10. Are there any megascopic features that can be used as keys to the amount of alteration present and/or degradation to be expected?

APPENDIX B — SUMMARY OF QUESTIONNAIRE RETURNS

? = Unknown
Y = Yes
NR = Not Run
x = status indicated

STATE	Exp. degrad.	MAT'L DEGRAD WILL PASS: L. A. wear	MAT'L DEGRAD WILL PASS: Soundness	MAT'L DEGRAD WILL PASS: Freeze-thaw	PROBLEM IS: Serious	PROBLEM IS: Mod. serious	PROBLEM IS: Insignificant	PROBLEM IS: Non-existent	CLASS'N OF MATERIAL DEGRAD	MATERIAL IS USED TO CONSTRUCT: PC concrete	MATERIAL IS USED TO CONSTRUCT: Asph. conc.	MATERIAL IS USED TO CONSTRUCT: Bit. surf	MATERIAL IS USED TO CONSTRUCT: Base	MATERIAL IS USED TO CONSTRUCT: Subbase	Tests for degradation	TYPE TEST	Are tests satisfactory?	Treatments to prevent degrad.	TYPE TREATMENT REMARKS	Megascopic ident. of degrad. possible?
ALABAMA	Y	Y + DeVal	Y	NR		x			Limestone Silica gravel Quartz	x	x	x	x	x	No	DeVal test used	—	No		
ARIZONA	Y Rare	Y					x		Volcanic tuffs				x	x	No			No		?
ARKANSAS	Y	Y	Y			x			Argillaceous limestone Argillaceous shale				x					No		
CALIFORNIA	Y	Y	Y		x	x			Weathered granite Schist Shales Sandstone Serpentine (weathered)	x	x	x	x		Y	100/500 LART	(1)	No	Limit time mixing PC concrete	Partial ident.
COLORADO	Y	No	Y	Y		x			Disintegrated granite Mica schist Sandstone	x		x	x	x	Y	LART with knowledge of local aggregates	Y	No	Crush to coarse side so after degrading, it's still OK. Bit. surf., adjust cold feed to fines in specs.	Rely on Lart; Meg.
CONNECTICUT	Y	No	No	No			x		Shale Sandstone Siltstone				x		Y	Scratch test Brass rod LART & soundness	Yes	No		
DELAWARE	No																			
FLORIDA	Y	Y	N		x		x		Limestone Slag	x	x	x				Scratch test	Help	No	Light rollers Pneumatic rollers	
GEORGIA	Y	Y	Y	Y			x		Mica gneiss Shales Dunite	x			x	x		Visual inspection		No		Visual insp.
HAWAII	No						x									Soundness	No	No		
IDAHO	Y	Y	Y	Y	x				Basalt Shale		x	x	x	x	Yes	LART modified	No	Yes	Special road oil and SS-1 treatments (Experimental project w/cement and lime)	No
ILLINOIS	Y						x		Illinois						Yes	Soundness	Yes			
INDIANA	Y	Y	Y	Y			x			x	x	x	x	x	Yes	LART + absorption	Yes	No		No
IOWA	Y	Y					x		Gravels Limestones Dolomitic limestones				x		No			No		
KANSAS	Y	Y	Y	Y		x			Limestone Calcareously bound sandstone	x	x	x	x	x	No	Low Sp. Gr. < 2.40 w/associated porosity permeability and poor resistance to impact and abrasion				
LOUISIANA	No							x												
MAINE	Y	Y				x			Sandstone		x	x			No			No		
MARYLAND	Y	Y	Y			x			Limestone Argillaceous limestone	x	x	x	x	x	No			Yes	Selective quarrying	
MICHIGAN	No							x												
MISSISSIPPI	No							x												
MISSOURI	Y			x	x				Shale Chert	x	x	x	x	x	No				Heavy media separation research	
MONTANA	Y	Y					x		Baked sandstone Shale Granite		x	x				No		No		
NEBRASKA	Y	Y	Y	Y			x		Argillaceous sedimentaries Basic igneous rocks Metamorphic rocks	x	x		x		No			No		
NEVADA	Y					x			Decomposed granite		x	x	x	x	No			Yes	Heavy seal coats on plant mix bituminous surface	

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THOD OF TEST FOR
I OF AGGREGATES

a quantitative measure of the degradation of
ing action of the aggregate against itself in
l under the action of the Idaho kneading com-

r hand stack of the following sieves:

,

n diameter steel mold.

l-inch through No. 200.

ne following gradation:

nch sieve and retained on the 1/2-inch;
nch sieve and retained on the 3/8-inch;
nch sieve and retained on the No. 4; and
sieve.

ative of the gradation of the material as

l portions of the sample shall be used in

the Los Angeles Rattler Degradation Test.
en dry condition, maximum drying temperature

dation Test sufficient material shall be
er having been compacted in a 4-inch diameter
2.1 to 3.0 inches. The specific gravity of
guide in this determination. This material
ater to have a moisture content slightly in
ontent.

ttler Degradation Test. The prepared materi-
les wear machine with the steel balls being

removed from the machine. The wearing action of this test is that of aggregate against aggregate. The machine is then rotated 1000 revolutions.

The material is removed from the machine and sieved through the Gilson mechanical shaker or the hand sieves. The weight of material retained on each sieve will be recorded and the percent passing calculated.

The portion of the material passing the No. 4 sieve will then be mixed thoroughly and portions split out for Liquid Limit, Plastic Limit, Sand Equivalent and a wash gradation.

B. Procedure for Kneading Compactor Degradation Test. The sample is placed in the steel mold in two approximately equal portions, each portion being rodded lightly to distribute the material in the mold. The sample shall then be subjected to 1000 blows of the compactor foot at 250 psi pressure.

Upon completion of compacting, the material shall be removed from the mold and split into two representative portions: One portion shall be used for sieve analysis; the other portion shall be used to determine the Sand Equivalent.

V. REPORT

A. Report on Los Angeles Rattler Degradation Test. The original gradation, L. L., P. I. and S. E., together with the final gradation, L. L., P. I. and S. E. are reported. The amount of degradation and type are indicated by changes in these test values.

B. Report on Kneading Compactor Degradation Test. The original gradation and Sand Equivalent, together with the final gradation and Sand Equivalent are reported. The amount of degradation and type are indicated by changes in these test values.

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